Claims

1. A method for determining the relative position of two objects comprising measuring the distance between said objects based on the use of one or more transducers or arrays of transducers functioning as transmitters of ultrasonic signals and one or more transducers or arrays of transducers functioning as receivers of said ultrasonic signals, and determining the degree of alignment therefrom.

2. A method according to claim 1, wherein at least one of the transducers or arrays of transducers functioning as receivers of ultrasonic signals is replaced by a reflector and at least one of the transducers or arrays of transducers functioning as transmitters of said ultrasonic signals also functions as a receiver of said signals.

3. A method according to claim 2, wherein a single transducer is used for transmitting an ultrasound signal and for receiving the echo that returns from a single reflector in order to determine the distance between said transmitter and said reflector by measuring the time of flight of said signal.

4. A method according to claim 1, wherein a single transducer is used for transmitting an ultrasound signal and a second transducer is used for receiving said signal in order to determine the distance between said transmitter and said receiver by measuring the time of flight of said signal.

5. A method according to claims 3 or 4, wherein the distance is determined from the time of flight by starting a clock simultaneously with the start of transmission of an ultrasonic signal and stopping said clock when the received signal rises above a predetermined threshold.

6. A method according to claims 3 or 4, wherein the distance is determined from the time of flight by transmitting an ultrasonic signal, sampling the received signal, and carrying out a cross-correlation with a stored reference signal.

7. A method according to claim 6, wherein the transmitted ultrasonic signal consists of a random sequence of pulses.

8. A method according to claim 7, wherein the transmitted random sequence of pulses is modulated by digital modulation.

9. A method according to claim 8, wherein the digital modulation is carried out by means of the PSK method.

10. A method according to any one of claims 1 to 9, wherein the distance between the transmitter and the receiver is measured by measuring the spatial phase difference between the transmitted and received wave.

11. A method according to claim 10, wherein the distance between the transmitter and the receiver is determined by using a transducer capable of transmitting ultrasonic signals at two different wavelengths and measuring the time of flight when the distance is relatively large and measuring the spatial phase difference between the transmitted and received wave when the distance between transmitter and receiver is less than one wavelength.

12. A method according to claim 1 or 2, wherein the distance between the transmitter and the receiver and/or reflector is determined by using a transducer capable of transmitting ultrasonic signals at least two different wavelengths and measuring the ratio of the intensities of the received signals at each wavelength.

13. A method according to claim 1, wherein a minimum of three transmitting ultrasonic transducers are mounted in a predetermined geometrical arrangement on, or near, one of the objects and a minimum of three receiving ultrasonic transducers are mounted in the same predetermined geometrical arrangement on, or near, the second object and the objects are aligned when the intensity of all of the individual received signals is maximized.

14. A method according to claim 13, wherein the alignment procedure is carried out within the Fresenel zone of the transmitted ultrasonic beams.

15. A method according to claim 13, wherein the transmitting transducers are focusing transducers that produce focused ultrasonic beams.

16. A method according to claim 13, wherein each of the transmitting transducers transmits a unique sequence of data bits and the objects are aligned when each of said unique signals is received by the mating receiving transducer and the intensities of all the signals are equal to predetermined values.

10035171.123101

17. A method according to claim 1 or 2, wherein the relative distance and alignment of the two objects is determined by use of triangulation techniques.

18. A method according to claim 17, wherein the relative alignment of the two objects is accomplished in three-dimensional space by using one ultrasonic transmitter located on, or near, one of said objects and three ultrasonic receivers located on, or near, the second object, measuring the lengths of the sides of the triangles formed by said transmitter and each pair of said receivers, and moving said transmitter until a predetermined relationship between said lengths of said sides of said triangles is achieved.

19. A method according to claim 17, wherein the relative alignment of the two objects is accomplished in two-dimensional space by using one ultrasonic transmitter located on, or near, one of said objects and two ultrasonic receivers located on, or near, the second object, measuring the length of the sides of the triangles formed by said transmitter and each pair of said receivers, and moving said transmitter until a predetermined relationship between said lengths of said sides of said triangles is achieved.

10035171.121301

20. A method according to claims 18 or 19, wherein the ultrasonic transmitter and the two or three ultrasonic receivers are replaced by two or three transmitters and one receiver.

21. A method according to any one of claims 17, 18, 19, or 20, wherein the ultrasonic transducers are single element transducers.

22. A method according to any one of claims 17, 18, 19, or 20, wherein the ultrasonic transducers are composed of an array of elements.

23. A method according to any one of claims 17, 18, 19, or 20, wherein an aperture is placed before the transmitting ultrasonic transducers or a diverging transducer is used to cause the transmitted ultrasonic beam to diverge.

24. A method according to claims 1 or 2, wherein two or more ultrasonic transmitters, or transmitter/receivers, are mounted on, or near, one of the objects, said transmitters being mounted at a predetermined, fixed angle such that the transmitted beams intersect at a point in front of said first object and one ultrasonic receiver or reflector is mounted on, or near, the second object which is displaced according to information received from intensity measurements until said receiver or reflector is

located at said intersection point, thus achieving proper positioning of said objects relative to each other.

25. A method according to claim 24, wherein the intersection point of the transmitted beams is located within the Fresnel zone of the ultrasonic transducers.

26. A method according to claim 24, wherein the ultrasonic transducers are focused and the intersection point of the transmitted beams is located at the focal points of said transducers.

27. A method according to claim 1 or 2, wherein two or more ultrasonic receivers or reflectors are mounted on, or near, one of the objects and one ultrasonic transmitter, or transmitter/receiver, is mounted on, or near, the second object said transmitter, or transmitter/receiver, being composed of an array that produces a beam that can be steered by electronic means in accordance with information received from measurements of the angles to said receivers until said angles are equal to predetermined values, thereby to achieve proper positioning of said objects relative to each other is achieved.

28. A method according to claim 2, wherein a single ultrasonic transducer, used to both transmit and receive the ultrasonic signals, is

mounted on, or near, one object and at least one reflector is mounted on, or near, the second object, said reflector being suitable to reflect back a pattern that can be translated into the position and orientation of said objects relative to each other.

29. A method according to claim 28, comprising a reflecting device consisting of two, or more, parallel reflecting planar surfaces intersected, at an angle of 90 degrees or less, by one or more planes to form one, or more, step-like configurations.

30. A method according to claim 28, wherein the reflector comprises two, or more, parallel reflecting planar surfaces separated by perpendicular surfaces to form one, or more, step-like configurations with a cylindrical symmetry created by drilling coaxial bores of different diameters.

31. A method according to claim 29 or 30, wherein some or all of the steps in a two or more step reflector have different depths.

32. A method according to claim 28, wherein two reflectors are mounted at right angles to each other.

10035712.121001

33. A method according to claim 29 or 30, wherein, for the case of reflectors having two or more steps, the total width of the steps does not exceed the beam width of the ultrasonic beam that impinges upon the reflector.

34. A method according to claim 29 or 30, wherein the distance between reflecting layers (step height) is equal or greater than the echo duration multiplied by the sound velocity in the medium divided by two.

35. A method according to claim 2, wherein the reflecting surfaces are surrounded with ultrasonic energy absorbing material.

36. A method according to claim 29, wherein the two objects to be positioned are located within a human or animal body, and are separated by at least one layer of tissue, and the air gaps, which occur between said tissue and the reflecting surfaces are filled with medical ultrasonic gel.

37. A method according to claim 29, wherein the two objects to be positioned are located within a human or animal body, and are separated by at least one layer of tissue, and the air gaps, which occur between said tissue and the reflecting surfaces are filled with a hard or

flexible material having an acoustical coefficient matching that of said tissue.

38. A method according to any of the preceding claims, wherein the distance is measured by the following steps:

- generating a repetitive series of short electrical pulses or bursts of electrical pulses;
- amplifying said pulses;
- applying said amplified electric pulses to a transducer which converts the electrical energy to ultrasonic energy;
- allowing said ultrasonic energy to propagate, in the form of a relatively narrow beam, through a medium, until it encounters either another transducer or a reflector which directs it back towards said transducer from which it was emitted;
- receiving said ultrasonic energy by said transducer which converts it to an electrical signal;
- amplifying and filtering said electrical signal;
- digitizing said signal;
- temporarily storing the sampled data in a separate buffer of a first-in first-out (FIFO) buffer or fast memory;
- transferring the data from the FIFO or fast memory into the main computer memory;

- correlating the data in each buffer with a predefined reference signal pattern stored in a computer memory;
- determining the time of flight of the ultrasonic signal from the index of said buffer where the correlation with said reference signal has its maximum value; and,
- determining the distance from said time of flight.

39. A method according to claim 38, wherein the predefined reference signal is generated from a properly chosen mathematical function.

40. A method according to claim 38, wherein an actual received ultrasonic signal is measured and stored in the computer memory to serve as the predefined reference signal.

41. A method according to any one of the preceding claims, wherein the alignment of the two parts relative to each other is determined by the following steps:
   - using a single transducer as the transmitter/receiver of the ultrasonic beam and a reflector having at least one-step, which will give at least two distinct signals in the return beam;
   - correlating the signals stored in the computer main memory with those of the predefined reference signal in the computer memory;

10035171.122101

- determining the step depths from the buffers corresponding to said maxima of said correlations, wherein, at least two local maxima of the correlation must exist and the difference(s) between them must correspond to the known depth(s) of the step(s);
- if the measured depth(s) of the step(s) do not agree with the known depth(s) of said step(s), then moving the transducer relative to the reflector and carrying out the correlation again; and
- when the measured depth(s) of the step(s) do agree with the known depth(s) of said step(s), then use the results of the correlation to determine the energy relation between said signals in said buffers.

42. A method according to claim 41, wherein the intensity maxima from the buffer are used to determine the alignment.

43. A method according to claim 41, wherein the ratio of the integration of the echoes is used to determine the alignment.

44. A method according to any one of the preceding claims, wherein the displacement of the objects relative to each other is determined and changed by the following steps:

10035474.121301

(a) using a single transducer as the transmitter/receiver of the ultrasonic beam and a reflector having at least two-steps of different depths, which will give at least three distinct echoes in the return beam;

(b) determining that the objects are not aligned if less than the expected number of echoes is returned;

(c) determining the depth of the steps from the returned echoes;

(d) comparing the measured depth with the known depths of the reflector, to determine the portion of the reflector upon which the ultrasonic beam impinges;

(e) check that the ratio of energy of the two echoes that match the step depth are within a certain relation;

(f) using the information obtained in the steps (d) and (e), to move the transmitter relative to the reflector; and,

(g) repeating steps (b) to (f) until the transmitter is positioned directly in front of the reflector.

45. A reflector of ultrasonic suitable to reflect back a pattern that can be translated into the position and orientation of said objects relative to each other.

10038747.121301

46. A reflector of ultrasonic energy according to claim 45, comprising two, or more, parallel reflecting planar surfaces intersected, at an angle of 90 degrees or less, by one or more planes to form one, or more, step-like configurations.

47. A reflector of ultrasonic energy according to claim 45, comprising two, or more, parallel reflecting planar surfaces separated by perpendicular surfaces to form one, or more, step-like configurations with a cylindrical symmetry created by drilling coaxial bores of different diameters.

48. A reflector of ultrasonic energy according to claims 46 or 47, wherein some or all of the steps in the step reflector have different depths and/or different lengths and/or different cross-sections.

49. Endoscopic device comprising a system for measuring the distance between and/or the relative alignment of two objects located at two different locations along the length of said endoscope comprising one or more transducers or arrays of transducers functioning as transmitters of ultrasonic signals located on, or near, one of said objects and one or more transducers or arrays of transducers functioning as receivers of said ultrasonic signals located on, or near, the other of said objects.

50. Endoscopic device according to claim 49, wherein at least one of the transducers or arrays of transducers functioning as receivers of ultrasonic signals is replaced by a reflector and at least one of the transducers or arrays of transducers functioning as transmitters of said ultrasonic signals also functions as a receiver of said signals.

51. Endoscopic device according to claim 50, wherein a single ultrasonic transducer, used to both transmit and receive the ultrasonic signals, is mounted on, or near, one of the objects and at least one reflector is mounted on, or near, the second object, said reflector being suitable to reflect back a pattern that can be translated into the position and orientation of said objects relative to each other.

52. Endoscopic device according to claim 51, comprising a reflecting device consisting of two, or more, parallel reflecting planar surfaces intersected, at an angle of 90 degrees or less, by one or more planes to form one, or more, step-like configurations.

53. Endoscopic device according to claim 51, comprising a reflecting device consisting of two, or more, parallel reflecting planar surfaces separated by perpendicular surfaces to form one, or more, step-like

configurations with a cylindrical symmetry created by drilling coaxial bores of different diameters.

54. Endoscopic device according to claim 52 or 53, wherein some or all of the steps in the step reflector have different depths.

55. Endoscopic device according to claim 51, wherein two reflectors are mounted at right angles to each.

56. Endoscopic device according to claim 49, wherein a single transducer is used for transmitting an ultrasound signal and a second transducer is used for receiving said signal in order to determine the distance between said transmitter and said receiver by measuring the time of flight of said signal.

57. Endoscopic device according to claim 49, wherein a minimum of three transmitting ultrasonic transducers are mounted in a predetermined geometrical arrangement on, or near, one of the objects and a minimum of three receiving ultrasonic transducers are mounted in the same predetermined geometrical arrangement on, or near, the second object and the objects are aligned when the intensity of all of the individual received signals is maximized.

58. Endoscopic device according to claim 57, wherein the transmitting transducers are focusing transducers that produce focused ultrasonic beams.

59. Endoscopic device according to claim 57, wherein each of the transmitting transducers transmits a unique sequence of data bits and the objects are aligned when each of said unique signals is received by the mating receiving transducer and the intensities of all the signals are equal to predetermined values.

60. Endoscopic device according to claims 49 or 50, wherein the relative alignment of the two objects is determined by use of triangulation techniques.

61. Endoscopic device according to claim 49, wherein the ultrasonic transducers are single element transducers.

62. Endoscopic device according to claim 49, wherein the ultrasonic transducers are composed of an array of elements.

63. Endoscopic device according to claim 49, wherein an aperture is placed before the transmitting ultrasonic transducers or a diverging transducer is used to cause the transmitted ultrasonic beam to diverge.

10035174 .122401

64. Endoscopic device according to claims 49 or 50, wherein two or more ultrasonic transmitters, or transmitter/receivers, are mounted on, or near, one of the objects, said transmitters being mounted at a predetermined, fixed angle such that the transmitted beams intersect at a point in front of said first object and one ultrasonic receiver or reflector is mounted on, or near, the second object which is displaced according to information received from intensity measurements until said receiver or reflector is located at said intersection point, thus achieving proper positioning of said objects relative to each other.

65. Endoscopic device according to claim 49 or 50, wherein two or more ultrasonic receivers or reflectors are mounted on, or near, one of the objects and one ultrasonic transmitter, or transmitter/receiver, is mounted on, or near, the second object said transmitter, or transmitter/receiver, being composed of an array that produces a beam that can be steered by electronic means in accordance with information received from measurements of the angles to said receivers until said angles are equal to predetermined values, thereby to achieve proper positioning of said objects relative to each other is achieved.

66. Endoscopic device according to claim 52 or 53, wherein, for the case of reflectors having two or more steps, the total width of the steps does

not exceed the beam width of the ultrasonic beam that impinges upon the reflector.

67. Endoscopic device according to claim 52 or 53, wherein the distance between reflecting layers (step height) is equal or greater than the echo duration multiplied by the sound velocity in the medium divided by two.

68. Endoscopic device to claim 50, wherein the reflecting surfaces are surrounded with ultrasonic energy absorbing material.

69. Endoscopic device according to claim 52 or 53, wherein the two objects to be positioned are located within a human or animal body and are separated between at least one layer of tissue and the air gaps, which occur between said tissue and the reflecting surfaces are filled with medical ultrasonic gel.

70. Endoscopic device according to claim 52 or 53, wherein the two objects to be positioned are located within a human or animal body and are separated by at least one layer of tissue and the air gaps, which occur between said tissue and the reflecting surfaces are filled with a hard or flexible material having an acoustical coefficient matching that of the tissue.

10035717.123101

71. Endoscopic device according to any one of the preceding claims, wherein an anvil unit of a stapler system is one of the objects to be aligned and a stapler deployment unit containing a stapler cartridge is the other object.

72. A stapler cartridge according to claim 71, wherein one or more reflectors of ultrasonic waves is created on or within or as an integral part of the surface of said cartridge.

73. A stapler cartridge according to claim 71, containing one or more channels created throughout its height for guiding an ultrasonic signal from a transmitter to a receiver of said signal.

74. A stapler anvil unit or a stapler cartridge according to claim 71, wherein the transducer that transmits only, or receives only, or both transmits/receives is mounted into said stapler anvil unit or said cartridge unit.

10036171.121301